REMARKS

The Present Invention and the Pending Claims

The present invention relates to a light-receiving element comprising a GaN group semiconductor material. Claims 2-7 are currently pending.

In particular, the Schottky barrier type light receiving element of the present comprises (a) a light receiving layer comprising a GaN group semiconductor, wherein the light receiving layer is a first conductivity type layer, (b) an electrode formed on one surface of the light receiving layer as a light receiving surface in such a manner that light can enter the light receiving layer, and (c) a depletion layer formed under the electrode, which depletion layer extends to cover an area around the electrode, wherein (i) the light receiving element is a Schottky barrier type light receiving element in which light enters the depletion layer from the side the electrode is formed, (ii) the electrode formed on the light receiving surface comprises at least a Schottky electrode, and (iii) a total of boundary lines between areas of the light receiving surface covered with the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface. The features of the present invention ensure that the light to be received does not pass a GaN group semiconductor layer, but can enter the depletion layer directly, even from the electrode side. Moreover, a device with these features exhibits superior sensitivity, even to light with wavelengths in the blue to ultraviolet range. In other words, a shorter wavelength does not decrease the device sensitivity.

Summary of the Office Action

The Office Action rejects claims 2-7 under 35 U.S.C. § 103(a) as allegedly obvious in view of Khan et al. (U.S. Patent No. 4,614,961) in combination with Pankove (U.S. Patent No. 4,028,720). Reconsideration of the pending claims is respectfully requested.

Discussion of the Obviousness Rejection

Khan et al. reportedly discloses a semiconductor light-receiving element with all of the properties recited in claim 2. The Examiner concedes that Khan et al. fails to teach at least that light enters the depletion layer from the side the electrode is formed and that the total of the boundary lines between areas of the light receiving surface covered by the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface, as required by the pending claims. Pankove allegedly discloses a photovoltaic device in which light enters the incident surface from the side the grid electrode

is formed and the total of boundary lines between areas of the light receiving surface covered with the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface (see Figure 1). According to the Examiner, it would have been an obvious modification to someone with ordinary skill in the art to modify the structure taught by Khan et al. to provide the additional features taught by Pankove in order to reduce internal resistance, improve electrical current flow, and optimize the area needed to receive light while minimizing the outer periphery.

Khan et al. discloses a UV detector **10** comprising a sapphire substrate **11**, a buffer layer **12**, an $Al_xGa_{1-x}N$ layer **14**, and a Schottky barrier **15**, which are laminated successively to one another (see Figure). As for the depletion layer, Khan et al. only describes "a photon (UV light from the flame) enters the depletion region under the Schottky barrier through the transparent Al_2O_3 substrate" (see col. 3, lines 27-30). Khan et al. does not teach or suggest a depletion region that extends to cover an area *around* the Schottky barrier. The detector of Khan et al. merely utilizes the depletion region under the Schottky barrier as a light receiving area.

Moreover, as mentioned above and conceded by the Examiner, Khan et al. does not teach or suggest "a total of boundary lines between areas of the light receiving surface covered with the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface." In other words, Khan et al. does not disclose a structure that enables light to enter the depletion region from the side where the Schottky barrier is formed (i.e., "a depletion region extends to cover an area around Schottky barrier" and "a total of boundary lines between areas of the light receiving surface covered with the Schottky barrier and exposed areas is longer than the length of the outer periphery of the light receiving surface"), as is required by the pending claims. In the detector of Khan et al., the light to be detected enters the depletion region, which is the light receiving area, from the side *opposite* to the side on which a Schottky barrier to block the light is formed (i.e., from the sapphire substrate side) (see Figure). In other words, the structure of the detector of Khan et al. is not intended even to allow entry of light from the side where the Schottky barrier is formed into the depletion region. Accordingly, those of ordinary skill in the art would not find any motivation to modify the detector of Khan et al. to allow for the entry of light from the side where the Schottky barrier is formed, into the depletion region.

In addition, the detector of Khan et al. utilizes the depletion region at the lower side of the Schottky barrier as a light receiving area. For improved sensitivity with such a structure, it is only necessary to enlarge the area of the Schottky barrier (thereby also increasing the area of the depletion region). It is clear, therefore, that those of ordinary skill in the art would not be motivated to use an electrode having a longer outer periphery, such as a grid electrode, for the detector of Khan et al. since such an improvement would not be necessary.

Pankove describes a P-N junction type semiconductor photovoltaic device 10 including a body 12 of silicon having gallium and arsenic paired molecular impurities. Regarding the Schottky barrier type element, Pankove refers to "Schottky barrier type devices" in col. 4, lines 51–59; however, it should be noted that this paragraph only teaches that silicon having gallium and arsenic paired molecular impurities can be used for Schottky barrier type devices. Pankove does not actually describe a Schottky barrier type element using a GaN group semiconductor or the idea of an electrode therefor. Inasmuch as the Schottky barrier is formed by a junction of a metal electrode and a semiconductor, those of ordinary skill in the art would readily understand that a simple application of the P-N junction type element illustrated in Figure 1 of Pankove to a Schottky barrier type element would not work.

As described above, the semiconductor photovoltaic device of Pankove is of a P-N junction type, which has a completely different structure from the Schottky barrier type light receiving element, and, therefore, the two types of devices are not comparable to one another. Moreover, the semiconductor photovoltaic device of Pankove does not have a light receiving layer comprising a GaN group semiconductor. Given such differences, those of ordinary skill in the art would not be motivated to turn to Pankove to obtain a Schottky barrier type light receiving element comprising a light receiving layer comprising a GaN group semiconductor.

Even if, for the sake of argument, the disclosures of Khan et al. and Pankove were combined, the resulting device would not be that of the present invention. As discussed above, Khan et al. does not teach "a depletion region which extends to cover an area around Schottky barrier" nor the feature in which "light enters to the depletion layer which extends to cover an area around electrode from the side the electrode is formed." Khan et al. also does not teach the feature in which "a total of boundary lines between areas of the light receiving surface covered with the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface." Pankove provides no description

whatsoever as to the depletion layer itself, not to mention a depletion layer extending to cover an area around the electrode, a light receiving layer comprising a GaN group semiconductor, or a Schottky barrier type light receiving element. In particular, Pankove fails to describe a depletion layer, which extends to cover an area around the electrode, and, as such, it does not teach or suggest the utilization of the depletion layer, extending to cover an area around the electrode, in an attempt to introduce light into the depletion layer from the side where the electrode is formed. In addition, Pankove merely discloses a grid electrode and fails to teach or suggest that "a total of boundary lines between areas of the light receiving surface covered with the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface." In the device of Pankove, the P-N junction inside the element is a light receiving area, and a grid electrode is adopted to allow entry of light into this light receiving area. In other words, in the device of Pankove, a grid electrode is employed only to provide a window to allow entering light to pass.

Thus, each of Khan et al. and Pankove fails to provide at least three common features recited in the pending claims: (1) "a depletion layer formed under the electrode, which depletion layer extends to cover an area around the electrode," (2) "light enters the depletion layer from the side the electrode is formed," and (3) "a total of boundary lines between areas of the light receiving surface covered with the Schottky electrode and exposed areas is longer than the length of the outer periphery of the light receiving surface." Therefore, even when combined, the references do not teach the Schottky barrier type light receiving element of the present invention as defined by the pending claims.

Because neither Khan et al. nor Pankove, either alone or in combination, teaches or suggests all the elements of the pending claims, or provide motivation for one of ordinary skill in the art to modify the device of either reference in the precise manner necessary to arrive at the present invention, the pending claims cannot be considered to be obvious in view of the cited references. Applicants respectfully request that the obviousness rejection be withdrawn.

Conclusion

The application is considered in good and proper form for allowance, and the Examiner is respectfully requested to pass this application to issue. If, in the opinion of the Examiner, a telephone conference would expedite the prosecution of the subject application, the Examiner is invited to call the undersigned attorney.

Respectfully submitted,

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